THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY

CHENNAI, TAMILNADU

SURGICAL MANAGEMENT OF CLUBFOOT BY MODIFIED CARROLL'S TECHNIQUE

DISSERTATION SUBMITTED FOR M.S. DEGREE

[BRANCH – II ORTHOPAEDIC SURGERY]

SEPTEMBER-2006

DEPARTMENT OF ORTHOPAEDICS
MADURAI MEDICAL COLLEGE AND
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CERTIFICATE

This is to certify that the dissertation entitled **"SURGICAL MANAGEMENT OF CLUBFOOT BY MODIFIED CARROLL'S TECHNIQUE"** is a bonafide record of work done by **Dr. B. MAHESH BABU** in the Department of Orthopaedics, Government Rajaji Hospital, Madurai Medical College, Madurai under the direct guidance of **Dr. A. RAJAMANI M.S. Ortho., D.Ortho.,** and overall guidance of me.

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ACKNOWLEDGEMENT

I owe my sincere and grateful acknowledgement to my beloved chief, **Prof. Dr.T. Prabhakaran M.S. Ortho., D. Ortho.,** Professor and Head of the Department of Orthopeadics and Traumatology, Madurai Medical College for his kind help, encouragement and guidance rendered to me in preparing this dissertation.

I am grateful to my beloved teacher and guide **Prof. Dr.A. Rajamani M.S. Ortho., D.Ortho.,** for his invaluable help and guidance rendered to me in preparing this dissertation.

I sincerely acknowledge the support rendered by my Additional Professors, **Prof Dr.M.Chidambaram, M.S. Ortho., D.Ortho., Prof. Dr.V. Pandiarajan, M.S. Ortho., D.Ortho., Prof. Dr.P.S.Shanmugam, M.S. Ortho.,D.Ortho.,** my Registrars **Dr. T. Chandraprakasam, M.S Ortho., D.Ortho., Dr.V.Raviraman, M.S. Ortho., D.Ortho.,** and all the Assistant Professors, Department of Orthopaedics, Madurai Medical College for their suggestions and guidance given to me during this study.

I express my gratitude to the babies, their parents, for their kind cooperation during this study.

My sincere thanks to the **Dean, Madurai Medical College,** Madurai for permitting me to use the hospital materials.

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INTRODUCTION

The clubfoot is the most common congenital orthopaedic condition requiring intensive treatment. As the clubfoot most likely represents a congenital dysplasia, treatment of idiopathic true clubfoot can never produce a normal extremity.

The basic objectives of treatment of clubfoot are

i) To correct abnormal tarsal relation.

ii) To maintain the reduction

iii) To establish muscle balance between evertors and invertors, dorsiflexors and plantar flexors.

iv) To provide mobile foot with normal function and weight bearing

Initial treatment of CTEV, is always mainly by nonoperative means of corrective manipulation, strapping, serial cast application and splinting. After a period of serial casting, if deformity persists or resists correction, soft tissue surgical release is indicated.

The rationale for soft tissue release is that realignment of the talus, calcaneum and navicular allows remodelling of the articular surfaces to occur. The first surgical procedure has to be done to achieve complete correction.

A variety of surgical procedures and techniques have been described to achieve the goal of complete anatomic restoration. The first description of a radical approach was published by **Codivilla** (1906). The one stage posteromedial release described by **Turco** (1971) has been the standard procedure in many centres; complete subtalar release was described by **Mckay** and **Simons** (1983).**Carroll** used two separate incisions, a curvilinear medial and a posterolateral incision to allow adequate exposure for lateral, posterior, plantar and medial release.

AIM

The aim of management of CTEV is to obtain a painfree, plantigrade, supple and functional foot which is cosmetically acceptable and normal footwear can be worn.

Surgical management of resistant or persistent clubfoot after conservative management needs more judgement and skill than any other orthopaedic condition amenable to surgical correction. There are innumerable soft tissue procedures described for primary correction of clubfoot.

The aim of this study is to evaluate the results of primary correction of clubfoot by modified Carroll's double incision technique.

HISTORICAL REVIEW

HIPPOCRATES (460-377 B.C) – described clubfoot and used manual manipulation and bandaging to achieve correction.

AMBROISE PARE (1575) – CTEV caused by pregnant women sitting crosslegged for too long, his treatment consisted of manipulations and bandaging.

NICHOLAS ANDRY (1743) – treated clubfoot with wet dressings, daily manipulation, fixation in splints of cardboard or wood.

ANTONIOS SCARPA (1803) – first detailed description of a clubfoot orthosis.

LORENZ (1784) – first performed the Achilles tenotomy.

DIEFFENBACH (1834) first to use a plaster cast in the treatment of clubfoot.

SOLLY (1857) – performed the first osteotomy and resecting entire cuboid bone in an adult male.

PHELPS (1884) – Reported his results of extensive posterior soft tissue releases.

OGSTON (1902) – advocated excision of the ossific nucleus of the talus, cuboid and calcaneus.

DENNIS BROWN (1930) – described his special splint for the treatment of clubfoot.

HIRAM KITE (1934) – Popularized serial plaster casting for correction of deformity.

IRANI and SHERMAN (1963) – described that medial deviation of neck of talus was the basic deformity in clubfoot.

TURCO (1971) – advocated a one stage posteromedial release.

LICHTBLAU (1972) – described lateral release in addition to medial release for correction.

MCKAY (1982) – advocated a complete subtalar release.

SIMONS (1985) - advocated a complete subtalar release and added release of both posterior talofibular and interosseus talo-calcaneal ligaments to derotate the calcaneum beneath the talus.

ILIZAROV (1960) – began using his circular external fixator. His research resulted in the theory of distraction histoneogenesis. In 1994, **B.B, JOSHI** invented his Joshi's External Stabilisation system for correction of CTEV.

ETIOLOGY & PATHOGENESIS

The true etiology of CTEV is unknown; most infants who have clubfoot have no identifiable genetic, syndromal or extrinsic cause.

Inheritance

Cowell & Wein concluded that idiopathic CTEV is primarily caused by a multifactorial inheritance system that is modified by intrauterine environmental factors and possibly is affected by a gene acting in a dominant fashion. Evidence for this is

- Incidence in the general population is 1.24/1000 live births
- Incidence in first degree relatives approximate 2.4 per 1000
- Incidence in second degree relative is 0.61 per 1000
- If one monozygotic twin has a CTEV, the second twin has only a 23% chance of having a CTEV.

Various theories of pathogenesis of clubfeet are

Germplasm Defect

Defective cartilaginous anlage - Irani and Sherman[9] found consistent defect in the anterior part of talus in dissected extremities of stillbirths and proposed the above theory.

Developmental arrest theory

Bohm postulated that, the cause of clubfoot was an arrest in embryonic development in the first stage. At the 9^{th} and 10^{th} weeks of intrauterine life, the embryonic foot has the characteristics of well developed equinus, inversion and metatarsal adduction

Fetal theory

Dunne postulated that mechanical block to development & extrinsic pressure in utero lead to development of CTEV.

Neurogenic theory

Isaacs and associates found histochemical anomalies in posteromedial and peroneal muscle groups. They conclude that the shortening of the posterior muscles resulted from a small increase of

fibrosis owing to minor changes in innervations occurring in intrauterine life. **Handelsman and Badalamente** reported similar findings.

Myogenic theory

Atrophy of the leg is a constant sign in congenital clubfoot; primary in the peroneal muscle group due to decrease in the size of the individual muscle fibers has been postulated.

Vascular theory

Hootnick et al. found that the majority of limbs with CTEV are associated with diminution of the anterior tibial artery and its derivatives; the diminution of the anterior tibial artery and its derivatives could result in medial tethering secondary to scarring or talar anlage dysplasia, thus leading to CTEV.

Retractive Fibrosis

Ippolito and Ponseti[8] identified an increase in collagen fibers and fibroblastic cells in the ligaments and tendons of the clubfoot. This hypothesis is supported by studies demonstrating abnormal ligamentous and fascial restraints in soft tissues that inherently resist deformity

correction. **Zimny** et al found myoblasts in medial fascia on electron microscopy and postulated them to cause medial contracture.

Teratologic clubfoot

The clubfoot can be associated with a teratologic disorder or syndrome complex; various conditions associated are

Arthrogryposis,

Diastrophic dysplasia,

Streeter's dysplasia,

Freeman – Sheldon syndrome,

Larsen's syndrome,

Myelodysplasia,

Mobius syndrome,

Pierre robin Syndrome,

Goldenhar syndrome,

Spinal muscular atrophy,

Muscular dystrophy &

Chromosomal abnormalities

PATHOANATOMY

The Pathological changes occur in bones, joints and soft tissues of the foot.

BONY DEFORMITIES

Talus

The talus is smaller than normal; the neck of the talus is short and medially deviated at an angle of more than 45° relative to the body of the talus compared with the normal 25°; medial and plantar deviation of the anterior end of talus is present. Body of the talus appears externally rotated within the mortise. Medial surface of talus is small and grossly deformed; Ossification centre is smaller than normal and eccentrically placed. Radiographic appearance is also delayed.

Calcaneum

Calcaneum is smaller than normal; sustentaculum tali is hypoplastic; posterior end is elevated, displaced posteriorly and laterally and lie close to fibular malleolus. Anterior end is deviated medially to lie more in line with the neck of the talus than normal. The os calcis is in

equinus. Inverted in the coronal plane so that its medial tuberosity approaches the medial malleolus.

Navicular

Medially subluxated, the navicular is rotated so that its long axis is nearly vertical, its tubercle may come into contact with the medial malleolus.

JOINT DEFORMITIES

Ankle joint

The anterosuperior articular surface of the talus is increased in breadth and the posterior part is poorly developed. Only 1/3rd of the lateral facet is in contact with the fibula, the anterior 2/3rd remaining uncovered. The medial surface is fully opposed to the medial malleolus but it becomes oblique.

Posterior Talocalcaneal joint

Anterior talocalcaneal joint is grossly abnormal or being absent; posterior talocalcaneal joint shows inversion and lateral displacement of calcaneus towards the fibula. In the horizontal plane, calcaneus rotates

medially so that its anterior end lies medially beneath head and neck of the talus.

Talo- Navicular joint

The navicular is displaced medially and articulates with the medial side and plantar surface of the head of the talus. The joint is not actually dislocated but is in extreme position of medial and plantar displacement. The navicular bone often develops a new facet medially where it may form an articulation with sustentaculum tali of the calcaneum.

Calcaneo- cuboid joint

Cuboid is displaced medially under the navicular and cuneiform bones; the calcaneus does not articulate fully with it. The remaining joints of the forefoot show some adduction. There is medial displacement of the distal portion of lateral column. Due to the first metatarsal being in severe plantar flexion than the fifth metatarsal, cavus deformity occurs.

Musculo- Tendinous Alterations

The tendocalcaneus is short and the medial portion of the tendon fans out to be inserted on the medial surface of the calcaneus which produces both equinus and hindfoot varus

The triceps surae, tibialis posterior, flexor hallucis longus and flexor digitorum longus are all short. The tendon of tibialis posterior is thickened distal to the medial malleolus and its insertion to the plantar structures broadened. The flexor hallucis longus does not groove the talus as it is displaced forwards and it passes almost vertically downwards over the inner surface of the calcaneum.

Atrophy of the leg is a constant sign in congenital clubfoot. The peroneal muscles are more atrophied than the other muscles and therefore unable to balance the foot.

A decrease in the number and size of fibres with an increase in fibrous connective tissue in gastrosoleus and in their tendon sheaths was described.

Alterations in the normal ratio of Type I and Type II fibers and atrophic fibers suggestive of altered innervations were found in triceps surae, tibialis posterior and flexor hallucis longus.

Ligamentous alterations

Contractures of the soft tissue maintains the pathologic malalignment of joints described as, equinovarus.

Posterolateral contractures ⟶ Posterior calcaneo fibular ligament,
posterior talo- fibular ligament,
superior peroneal retinaculum,
peroneal tendon sheaths.

These structures resist dorsiflexion and was termed as “Posterolateral tether”.

Medial contractures ⟶ Deltoid ligament
calcaneonavicular ligament,
talonavicular capsule and
dorsal talonavicular ligaments

These structures resist reduction of talonavicular subluxation and was termed as “medial tether”.

Posterior contractures ⟶ Posterior talofibular ligament,
ankle joint capsule, subtalar joint capsule

Plantar contractures ⟶ Bifurcated ‘Y’ ligament
long plantar ligament,
plantar calcaneo – cuboid ligament

The above pathoanatomy of a severe clubfoot has been drawn from clinical studies, dissections, surgical observations, serial sections and three dimensional computer analysis of clubfoot.

RADIOGRAPHIC EVALUATION

Imaging studies generally are not required to understand the nature or the severity of the CTEV. Radiographs are a useful base line prior to and following surgical correction of CTEV.

Adequate roentgenograms should be obtained

- To assess the degree of subluxation of talocalcaneal and talonavicular joints before treatment.
- To guide progress during conservative or operative treatment
- To determine whether correction has been maintained

Standard Roentgenograms include

i. Anteroposterior view of both feet.

ii. Stress dorisflexion lateral view of both feet – SIMULATED WEIGHTBEARING in infants

In older child, Anteroposterior and lateral standing roentgenograms can be taken

Technique

The patient's feet must be placed in identical and maximally corrected position while taking standard pictures.

Anteroposterior film is taken with foot 30° plantar flexed, tube angled 30° cranially from the perpendicular.

Normally, in the lateral view the axis of the talus is aligned downwards and in line with the axis of the first metatarasal. The axis of the calcaneus its slightly aligned upwards. The lines drawn along the axis of these bones meets at an angle of 20° to 40° (Talocalcaneal angle)

The angle between the axis of calcaneus and tibia in stress lateral view normally measures 10° to 40° (Tibiocalcaneal angle)

In the Anteroposterior view, the long axis of the talus passes through the long axis of first metatarsal the long axis of calcaneus passes through fourth metatarsal. In Anteroposterior view, talocalcaneal angle normally measures 30° to 55° (Kite's angle).

In the Anteroposterior view, the angle between the axis of talus and that of the first metatarsal measures 5° to 15°.

The Anteroposterior and lateral talocalcaneal angles when summated forms talocalcaneal index, which should be more than 40°, when the CTEV is fully corrected.

Talus – I metatarsal angle indicates forefoot adduction. Talocalcaneal angle in anteroposterior view indicates heel varus.

Tibio calcaneal angle in stress lateral view indicates equinus.

In CTEV, Anteroposterior – talocalcaneal angle will be less than 20°, lateral talocalcaneal angle will be less than 35° and talus- first metatarsal angle will be negative.

CLASSIFICATION AND EVALUATION

The lack of a universally accepted method of evaluating the severity of deformity prior to correction and improvement after treatment, has hindered the assessment of the validity of the various concepts of treatment.

Simons stressed the importance of differentiating between classification and evaluation of clubfeet. Classification divided clubfeet in to various groups based on examination at birth or at the time of reexamination following recurrence .Evaluation indicates strictly to treatment phases to determine the specific treatment to he undertaken and to monitor the results.

Classification was based on clinical criteria and helped to establish the prognosis. Evaluation was more comprehensive in that it included clinical, radiological and functional criteria.

At least two or three main varieties of clubfeet are present at birth (Cummings & Lovell)

1. Mild postural type which can be corrected passively without difficulty.
2. Moderate resolving type comprising the majority , which requires gentle manipulation and realignment followed by corrective casting
3. A severe rigid type which almost always needs surgical correction

Dimeglio[5] describes four basic categories of CTEV based on reducibility

1. Benign (Grade – I)
2. Moderate (Grade - II)
3. Severe (Grade - III)
4. Very severe (Grade - IV)

Coleman has classified clubfeet on the basis of response to treatment into various categories

i) A resistant type which fails to be corrected by nonoperative means

ii) A relapsed type in which correction was achieved by either nonoperative or operative means but which has recurred

iii) A neglected type, where in no treatment was undertaken during infancy.

Cummings et al evaluated 85 parameters of history, physical examination, radiographs and function used by different authors in an interobserver study; 37 of these 85 criteria were evaluated for inter observer error in assessment .

Carroll used simple 10 points scoring system for the preoperative evaluation based on anatomic criteria. Each of the following criteria can be given one point on a 10 - point scale

1. Calf atrophy
2. The position of the bimalleolar axis
3. Creases
4. Curved lateral border
5. Cavus
6. Fixed equinus
7. Navicular fixed to medial malleolus
8. Oscalcis fixed to fibula
9. Midtarsal mobility
10. Forefoot supination

Catterall has developed method of assessment of clubfoot deformity based on a dynamic concept of the foot, thorough knowledge of movements of foot and by defining a particular foot in terms of its fixed deformities. The method of assessment helped to identify a resolving pattern of clubfoot resulting from either tendon contracture or joint contracture.

The development of standardized method for the radiographic evaluation of the clubfoot by **Simons**[15] and the use of this method of analytical radiography in identifying various deformity combinations have contributed significantly to the objective assessment of severity .

Mckay developed an overall rating of the results of his circumferential release which was based on an arbitrary assignment of 180 points to a normal foot. Deformity, loss of ankle mobility, loss of function and pain were assigned values proportional to their deviation from the normal foot and subtracted from the standard.

Atar, Lehman et al devised a functional rating system for evaluating the results of operated clubfoot. The rating combined subjective and objective clinical assessment and radiographic criteria with

a normal foot being 100 points. The results could be evaluated as excellent with 85 to 100 pts, good with 70-84pts, fair with 60-69pts, and poor being less than 60pts.

NON OPERATIVE TREATMENT

Initial treatment for idiopathic clubfoot is nonoperative. Earlier the treatment is began, the most likely that it will be successful, due to relatively viscoelastic character of the newborn foot. The ligaments of the newborn are still lax under the influence of maternal sex hormones and the treatment is relatively easy.

The objective of the manipulations is to stretch the soft tissue contractures which are maintaining the abnormal tarsal relation. The two methods that seem to be most widely practiced and that have the highest reported success at long term follow up are the **Kite** [10]**/ Lovell** technique and the **Ponseti**[13] technique.

Sequential correction of the deformities has to be done. The forefoot deformities are corrected first, followed by hindfoot varus, the hindfoot equinus is corrected at last. Above knee casts are used routinely which are changed fortnightly. At the end of 4 to 5 manipulations, the correction is evaluated clinically. At that time, it is apparent that the foot is easy or resistant.

Correction is usually obtained by the end of fourth month and has to be maintained. After complete correction is obtained , the foot is splinted with a Dennis- Browne splint for 24 hours/day & removed for passive stretching and exercises during feeding time; when the child begins to walk, Dennis- Brown shoes are supplied with use of D.B. splint at nights. Corrective shoes has to be used until the age of 6 years to avoid recurrence.

SURGICAL TREATMENT

Indications

a. Deformities that do not respond to conservative treatment by serial manipulation and casting.

b. Type of surgery in the treatment of club foot is tailored to the age of the child and to the deformity to be corrected.

Timing of surgery

(1) With manipulation and serial casting, if good correction has not been obtained by 3 months, surgical management may be essential.

(2) Surgery can be done any time beyond 3 months of age and the child is thriving well and at least 12 pounds of weight.

(3) Size of the foot should be equal to or greater than 8 cm in length.

There is a lot of growth in the foot during the first year of life and therefore great potential for remodeling. If the bony architecture is

properly aligned at an earlier age, this should promote congruous development of the subtalar, calcaneocuboid and talonavicular joints.

Treatment by age

(1) **Soft Tissue Procedures** – In children less than 5 years, correction can be achieved by soft tissue procedures.

(2) **Bony Procedures** – In children more than 5 years, correction can be achieved only by bony procedures along with soft tissue procedures.

(3) If the foot is mature, triple fusion may be needed

VARIOUS SOFT TISSUE PROCEDURES

One stage posteromedial release -TURCO[17]

Useful in mild deformities with no severe internal rotational deformity of the calcaneus.

Incision – single medial incision extending from the first metatarsal base, passes proximally under the medial malleolus to the tendocalcaneus.

Disadvantages of this incision are

a. It crosses the skin creases on the medial side of the ankle, can lead to wound break especially at the corner of vertical and medial limb.
b. Exposure of the plantar fascia is difficult
c. The posterolateral structures, i.e, calcaneofibular and talofibular ligaments are difficult to see.

Turco emphasized correcting the deformity of the calcaneus beneath the talus which required complete subtalar (lateral, medial and posterior) release, as well as release of calcaneofibular ligament.

All medial neurovascular structures and tendons are identified. Tibialis posterior tendon is released. Tendocalcaneus and long toe flexors are lengthened and repaired; capsules of talonavicular joint, (dorsally, medially & inferiorly), Calcaneocuboid joint, (medially), Subtalar joint, Calcaneocuneiform joint and cuneiform-metatarsal joint are all released.

Interosseus talocalcaneal ligament is incised. Anterior part of deltoid ligament and calcaneonavicular ligament are sectioned .Henry's

knot and mass of scar an medial side of talonavicular joint are excised. Reduced talonavicular joint is pinned with ‘K’ wire.

Turco immobilized his patients for a total of 4 months, removing the ‘K-wires at 6 weeks. Night splints were used for an additional year following the end of cast immobilization.

Carroll double incision technique[2]

The child is positioned prone. Two incisions are used – a curvilinear medial incision and a postero lateral incision. The land marks for the medial incision are the centre of the os calcis, the front of the medial malleolus and the base of the first metatarsal. These three points define a triangle. The incision is parallel with the base of the triangle, but curved in the plantar direction proximally and over the dorsum of the foot distally. The posterolateral incision runs obliquely from the midline of the distal calf posteriorly to a point midway between the tendocalcaneus and the lateral malleolus.

Advantages of the skin incisions are

(a) Give excellent exposure of the entire anatomy.

(b) To allow protection of the neurovascular structures

(c) To promote good healing with minimal scarring and good cosmesis.

(d) To preserve the tendon sheaths for the tibialis posterior, flexor hallucis and flexor digitorum.

Through the medial incision, the abductor hallucis is exposed and freed from the os calcis. The plantar fascia, flexor digitorum brevis and abductor digiti minimi are freed from the os calcis. At the tip of medial malleolus, the sheath of the flexor digitorum longus is opened and followed distally to Henry's knot, where the flexor hallucis longus is identified.

The sheath of the peroneus longus tendon is identified and opened. The short and long plantar ligaments are divided. The calcaneocuboid joint is opened by dividing the superior, medial and plantar capsule.

Through the posterolateral incision, sural nerve and short saphenous vein are identified and protected by retraction in a lateral direction. The tendocalcaneus is exposed and divided in the sagittal plane separating the distal medial half from the os calcis and the proximal lateral half from the triceps surae. The deep fascia overlying the flexor

hallucis longus and neurovascular bundle is opened, the bundle is freed distally to the level of the subtalar joint.

Dissection is continued medially, and the fascia overlying the flexor digitorum longus and tiblialis posterior is opened. The tibialis posterior tendon is identified and divided by means of a ‘Z’ plasty. A narrow retractor is placed underneath the flexor hallucis longus, neurovascular bundle and flexor digitorum longus. The posterior capsule of the ankle and subtalar joint is opened and the tight posterior calcaneofibular ligament are divided. The posterior portion of the deltoid ligament is divided behind the flexor digitorum longus. Talonavicular joint is opened circumferentially. The slips of the tibialis posterior that run forward to attach to the undersurfaces of cuneiforms and bases of second through fourth metatarsal are divided.

After inserting ‘K’ wire posteriorly, the body of the talus is internally rotated in the ankle mortise and the os calcis is rotated externally. When the body of the talus is reduced into the ankle mortise and divergence has been restored between the long axis of talus and os calcis, supination and adduction deformity of the fore foot are corrected.

The ‘K’ wire previously inserted in the talus is advanced across the reduced midtarsal joint & through the skin on the dorsum of the forefoot proximal to the bases of the phalanges. Repair of tendons with the foot held in a plantigrade position. The knee is kept in extension in the immediate postoperative period to facilitate venous drainage.

Limb is treated in an above knee cast for 8 weeks with cast changes every 3 wks. When the cast is removed the foot is treated in an orthosis until the child is walking and there is clinical and radiographic evidence of a plantigrade foot.

Carroll[2] emphasized the plantar fascial release and capsulotomy of the calcaneocuboid joint since forefoot adduction and supination were not addressed by Turco’s procedure.

Extensile release –Mckay procedure[11,12]

Cincinnati incision-transverse circumferential incision is used. This incision provides excellent exposure of the subtalar joint and is useful in patients with a severe internal rotational deformity of the calcaneus. Great care must be exercised to preserve the vessels that supply heel flap. Since loss of heel flap will not only mean loss of correction but

exposure and infection of calcaneus . Tension on the suture line is another potential problem.

The majority of peritalar structures including all hind foot and midfoot joints are released. A medial and lateral circumferential talocalcaneal release is performed.

Complete release of the talonavicular and calcaneocuboid joint are included and both of these are pinned. The subtalar release includes the interosseus ligament. Once the calcaneus is adequately derotated by pushing the anterior end laterally and posterior tuberosity medially and downward, the interosseus ligament is internally fixed.

Complications

(1) Wound Infection

(2) Wound dehiscence

(3) Failure to achieve correction/Loss of reduction

(4) Hindfoot Valgus ,Calcaneus deformity

(5) Dorsal subluxation of the navicular

(6) Dorsal bunion

(7) Persistent medial spin.

(8) Avascular necrosis of talus

(9) Anaesthetic foot

Hind foot valgus deformity may occur due to

Division of deep deltoid ligament (or)

Complete release of interosseus talocalcaneal ligament without fixation.

Calcaneus deformity results from overlengthening of tendocalcaneus (or) from postoperative casting in excessive dorsiflexion.

Postoperatively, the foot is initially held in slight equinus, if there is tension on the skin closure to avoid necrosis of skin edges. At the 14^{th} postoperative day, cast can be changed with correction of residual equinus.

Bony procedures along with soft tissue procedures

(1) **Metatarsal osteotomy** – Indicated for metatarsus adductus deformity; in age group more than 5 yrs.

(2) **Dwyer's osteotomy** – for hind foot varus deformity. Medial open wedge calcaneal osteotomy.

(3) **Dillwyn Evans procedure** – Medial and posterior soft tissue release together with excision and fusion of calcaneocuboid joint; shortens lateral column of foot.

(4) **Lichtblau procedure** – Indicated for hind foot varus along with residual internal rotation of calcaneus. Medial release with lateral closing wedge osteotomy of the calcaneus.

(5) **Triple arthrodesis** – Adolescent with residual hindfoot, midfoot and forefoot deformity.

MATERIALS AND METHODS

At our institution, we selected 20 severe resistant clubfeet of 17 children for this prospective study. The age group varied from a minimum of 5 months to a maximum of 18 months and average age was 8 months. The duration of the study was from November 2003 to January 2006. The maximum follow up was 14 months. Average follow up was 10 months.

Of the 17 children, right side was involved in 5 cases and left side was involved in 9 cases; 3 cases were bilateral. Of 20 clubfeet, 8 were of grade III severity and 12 were of grade IV severity.

All the club feet were initially treated by serial long leg plaster of paris cast using kite's method[10] upto the age of 4 months or 6 to 7 cast. Plasters were changed every 2 weeks. After it was determined that the deformity could not be corrected with 4 months of serial casting, the feet was considered resistant and surgery was contemplated.

SELECTION CRITERIA

1. Age of the child between 4 months and 2 years
2. Resistant clubfoot
3. Severe and very severe clubfoot

EXCLUSION CRITERIA

1. Teratologic clubfoot, i.e., clubfoot secondary to neuromuscular causes like cerebral palsy and Arthrogryposis multiplex congenita.
2. Relapsed clubfoot
3. Recurrent clubfoot
4. Neglected clubfoot

All the cases had preoperative radiographs to assess degree of deformity. Radiographic assessment consisted of anteroposterior talocalcaneal angle, lateral talocalcaneal angle and talocalcaneal index.

TABLE 1

SEX RATIO

Sex	No	Percentage
Male children	11	64.7
Female Children	6	35.3

TABLE 2

INVOLVED SIDE

No. of cases	Bilateral	Unilateral		
		R	L	Total
17	3	5	9	14

TABLE 3

TIMING OF SURGERY

Age group (in months)	Modified Carroll's procedure	
	No.	Percentage
5 – 8	12	70.6
9 – 11	3	17.6
12 – 15	1	5.9
16 – 18	1	5.9
Total	17	100
Mean	8	
S.D.	3.64	

TABLE 4

PREOPERATIVE GRADING OF SEVERITY

Dimeglio Grade	No. of Clubfeet	Percentage
Grade III	8	40%
Grade IV	12	60%

SURGICAL TECHNIQUE

Anaesthesia and position

Under general anaesthesia in a semilateral position, we operated all our cases. Tourniquets were used throughout the surgery to ensure a bloodless operating field.

Double Incision

Curvilinear Medial Incision

The landmarks for the medial incision are the centre of the os calcis, the front of the medial malleolus and the base of the first metatarsal. These three points define a triangle. The incision is parallel with the base of the triangle but curved in the plantar direction proximally and over the dorsum of the foot distally.

Posterolateral incision – runs obliquely from the midline of the distal calf posteriorly to a point midway between the tendocalcaneus and the lateral malleolus.

Procedure

Through the posterolateral incision, the sural nerve and short saphenous vein were identified and protected. Lengthening of tendocalcaneus was done by a sagittal ‘Z’ plasty technique detaching the medial half of the tendon from the calcaneus. The deep fascia overlying the flexor hallucis longus and neurovascular bundle is opened. Tibialis posterior was identified and lengthened. The posterior and lateral capsule of ankle and subtalar joint was opened. The tight posterior calcaneofibular and posterior talofibular ligaments were divided. The posterior portion of the deltoid ligament was divided.

Through the medial incision, the abductor hallucis was freed from the oscalcis. The plantar fascia was incised and Henry’s knot was sectioned. The flexor hallucis longus and flexor digitorum longus together with the neurovascular bundles were retracted in the plantar direction. The long and short plantar ligaments were divided. Calcaneonavicular ligament was divided. Capsulotomy of the talonavicular joint and calcaneocuboid joint were done. With the foot in a plantigrade position, we verified correction obtained. In needed cases, intramuscular recession of flexor hallucis longus and flexor digitorum longus tendon were done.

With the foot held in plantigrade position, the tendocalcaneus and tibialis posterior were repaired. Wound closed and compressive dressing applied. Above knee slab applied. We did not use ‘K’ wire to stabilize the joint.

Postoperative Protocol

Under anaesthesia on 14th postoperative day, we removed the sutures and applied long leg cast with knee in 70° flexion and ankle and foot in neutral position.

On subsequent followup, we applied Plaster of Paris cast for 12 weeks postoperative period. The cast was changed every 2 weeks. We applied orthosis subsequently till the child started walking. Later clubfoot boot was given to maintain correction. Postoperative radiographs were taken to assess radiological correction.

From the original Carroll double incision technique, we adopted the following modifications. We operated all the cases in semilateral position. We did not use ‘K’ wire to stabilize the joint. We applied plaster of paris slab with knee in flexion in the immediate postoperative period.

RESULTS

All the wound healed primarily without infection and breakdown.

Residual deformities were present in 3 cases. One child had residual forefoot adduction and supination. Two other children had residual forefoot adduction deformity. Residual deformities in all the three children were mouldable and we are treating these children with corrective cast itself.

Good results were achieved in 17 of the 20 clubfeet (85%).

We evaluated our results using **Dimeglio**[5] method of grading severity of clubfoot. Each major component of clubfoot (ankle equinus, heel varus, derotation of calcaneopedal block and forefoot adductus) are graded clinically from 4 to 1 (most severe to mild).

Additional points are added for deep posterior and medial creases, cavus and poor muscle function. Total score is stratified into four groups of severity (Benign to very severe, Grade I to IV).

TABLE 5

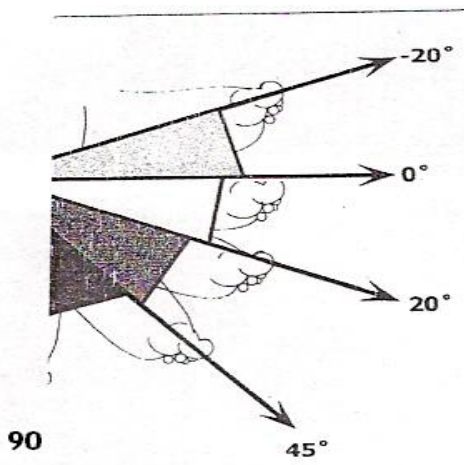
DIMEGLIO METHOD

Grade	Type	Points
I	Benign	<5
II	Moderate	=5<10
III	Severe	=10<15
IV	Very severe	=15<20

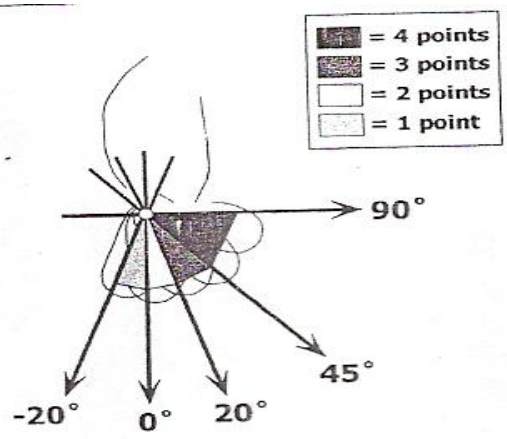
Reducibility	Points	Other Parameters	Points
90° - 45°	4	Posterior crease	1
45°- 20°	3	Medial crease	1
20°-0°	2	Cavus	1
<0° - 20°	1	Poor muscle function	1

DIMEGLIO METHOD

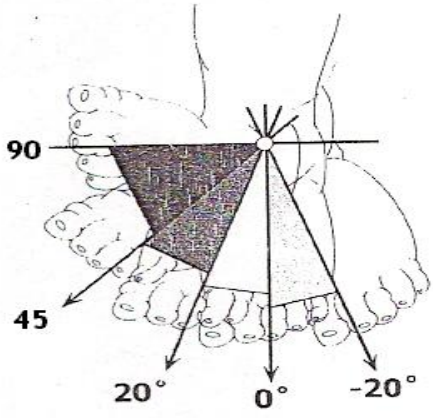
Grading based on severity of deformity



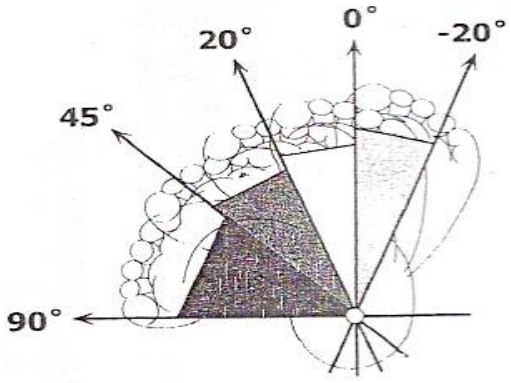
Evaluation of Equinus



Evaluation of Varus



Evaluation of derotation of calcaneopedal block



Evaluation of fore foot adduction

TABLE 6

RESULTS OF GRADE III CLUB FEET

Serial No.	Preoperative points	Postoperative points
1	11	4
2	10	4
3	11	4
4	10	4
5	12	4
6	11	4
7	11	4
8	10	4

TABLE 7

RESULTS OF GRADE IV CLUB FEET

Serial No.	Preoperative points	Postoperative points
1	16	4
2	15	4
3	15	4
4	15	4
5	15	4
6	16	4
7	15	7
8	16	6
9	15	4
10	16	4
11	15	7
12	15	4

TABLE 8

POSTOPERATIVE GRADE

Dimeglio Grade	No. of club feet	Percentage
Grade I	17	85%
Grade II	3	15%

TABLE 9

RESULTS

Preoperative Grade	No. of club feet	Post operative Grade
IV (Very severe)	12 → 9 12 → 3	I (Benign) II (Moderate)
III (Severe)	8 → 8	I (Benign)

Of 12 very severe club feet, 9 feet improved to benign grade and 3 feet improved to moderate grade. All the 8 severe club feet, improved to benign grade after surgery. We achieved good results in 85% of cases.

RADIOLOGICAL EVALUATION

TABLE 10

Angle / index	**Preoperative value**	**Postoperative value**	**Mean change**
Antero posterior Talocalcaneal Angle	13.4±4.35	25.5± 3.17	12.1
Lateral Talocalcaneal Angle	6 ±2.42	17.4± 4.11	11.4
Talocalcaneal Index	19.4± 4.86	42.9 ±4.56	23.5

The mean change in radiographic parameters achieved by correction is shown in Table 10. The postoperative mean talocalcaneal index achieved was 42.9º (Normal range > 40°). The postoperative mean anteroposterior talo-calcaneal angle was 25.5º (Normal range 30º to 55º). The Postoperative mean lateral talo-calcaneal angle was 17.4º (Normal 20º to 40º).

DISCUSSION

The goal of treatment of clubfoot is to obtain a painless, plantigrade, pliable, normal looking foot with good function.

Codivilla in 1906, first described a radical approach in treating clubfoot. **Brockman** described his extensive soft tissue release (in 2 stages) in 1930. The importance of early surgical release was emphasized by **Attenborough** in 1960. **Turco** described his one stage posteromedial release in 1971. The **Cincinnati** incision was later described by **Crawford** et al[3]. to allow complete subtalar release.

Long curved posteromedial incision affect wound healing. Hypertrophic and contracted scar may result. Scar itself acts as deforming force, producing residual deformity and stiffness. Release of calcaneocuboid joint and release of posterolateral tether are difficult. Exposure of plantar fascia is also difficult.

Circumferential **Cincinnati** incision does not allow as complete a posterior release as **Carroll's** approach would allow, especially in severe resistant cases. In **Cincinnati** incision, heel flap vascularity is also at risk.

Carroll's approach provides good exposure of the entire pathological anatomy without compromising wound healing. Especially in severe cases, the posterolateral tether is the main causative factor for equinus deformity. **Carroll's** approach allows good access to the posterolateral tether.

On Reviewing Literature,

Porat et al, **Depuy** and **Drennan, Franke** and **Hein** proposed that the best results are obtained with early operation i.e., between fourth and sixth months of life.

Otremski et al found that forefoot correction was inadequate in the Turco procedure unless plantar release was added to the procedure and the fact that the tibialis posterior tendon is removed, may be a source of secondary valgus deformity in some patients.

Yngve et al whose procedure involve, club foot release without wide subtalar release, reported that 82 percent of their surgeries resulted in a satisfactory functional rating.

Manzone et al reported no significant differences in functional results in clubfoot treated with posteromedial release and complete extensive release.

Yamamoto and **Furuya**, **Thompson** et al reported good correction and function in 75% to 85% of cases with **Turco'**s procedure.

Howard and **Diaz** reported 87% satisfactory results with posteromedial and lateral release. Their results improved in ensuring that calcaneocuboid joint was properly reduced.

Carroll et al reviewed their results and found that 81% of the patients had a satisfactory result.

Bensahel believed that the extent of the surgery should be matched to the complexity of the club foot deformity – "a la carte" approach.

TABLE 11

Study	No. of club feet	Results	Follow up
Yoneda and Carroll	84	82% good results	5 years
Hee, Hwan-Tak, Lee	58	85% good results	5.5 years
Porat	33	82% good results	5 years

Yoneda and **Carroll**[18] reviewed the results of surgical correction of 84 severe clubfeet by **Carroll's** double incision technique at 5 years follow up. They achieved good results in 82% cases.

Porat[14] reviewed 33 severe clubfeet treated by **Carroll's** double incision technique after an average of 5 years follow up. 82% cases had satisfactory results.

Hee, **Hwan – Tak**, **Lee**[7] reviewed 58 severe clubfeet treated surgically using **Carroll's** approach after an average follow up of 5.5 years. 85% cases had good results.

David Roye and **Benjamin Roye**[4] in their study, compared long tem results of the **Carroll** procedure with those of limited posterior release. They found that patients undergoing the **Carroll** procedure had significantly fewer surgeries and less stiffness.

Haesbeck and **Wright**[6] found that on an average of 28 years after surgery, patients who had comprehensive release had fewer operations, more complete correction of heel varus and improved subtalar motion when compared to those with isolated posteromedial release.

In our series, we achieved good results in 85% cases. We did not encounter wound healing problems. All the wound healed primarily without infection and breakdown. In this study, three children had residual deformities. Forefoot adduction was present in all the three children and in addition, one child had supination of the forefoot. In our short term follow up, we have obtained morphologically normal looking and supple foot in all the cases. We need longer term follow up to assess functional

outcome, gait pattern, size of foot, pain, mobility of ankle and subtalar joint.

Limitations of this study

1. Less number of cases in the study (20 clubfeet)
2. Shorter period of follow up (Average 10 months)

CONCLUSION

Carroll's dual incision technique offers goods exposure to the posterolateral, subtalar and medial structures without wound healing problems. This technique gives supple and cosmetic foot.

With our limited experience in this technique, it is definitely a procedure of choice in the surgical management of severe resistant club foot.

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PROFORMA

NAME : **AGE:** **SEX:**

ADDRESS :

I.P. NO : **DOA** **DOS** **DOD**

HISTORY

CONSANGUINOUS / NON CONSANGUINOUS MARRIAGE

FAMILY H/O CTEV

MODE OF DELIVERY

PREVIOUS TREATMENT DETAILS

DIAGNOSIS

UNILATERAL / BILATERAL

DIMEGLIO GRADE

PREOPERATIVE RADIOGRAPHIC ASSESSMENT

AP TALO-CALCANEAL ANGLE

LAT TALO-CALCANEAL ANGLE

TALO CALCANEAL INDEX

TREATMENT

DATE OF SURGERY

PATIENT POSITION

SPECIFIC PROCEDURES

COMPLICATIONS

WOUND STATUS

RESIDUAL DEFORMITY

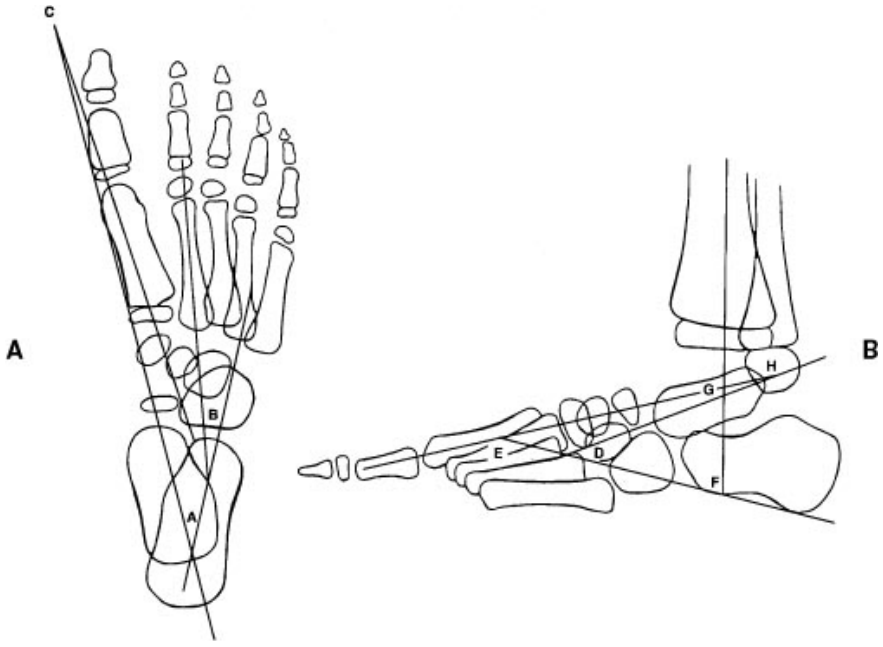
STIFFNESS OF FOOT

POSTOPERATIVE ASSESSMENT

DIMEGLIO GRADE

RADIOGRAPHIC ASSESSMENT

RADIOGRAPHIC FEATURES OF CTEV



A – Antero posterior talo calcaneal angle

C – Antero posterior talus I metatarsal angle

D – Lateral talo calcaneal angle

F – Tibio calcaneal angle

ANTERO POSTERIOR VIEW

LATERAL VIEW

SURGICAL INCISION

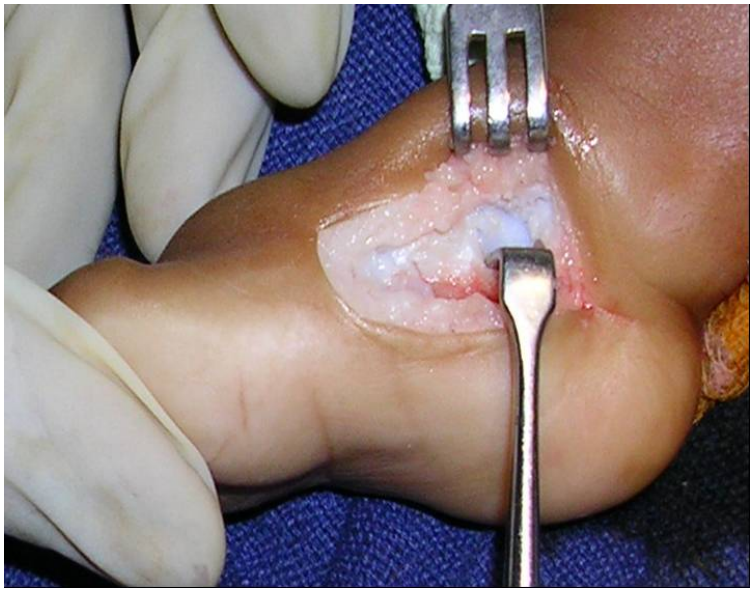
MEDIAL INCISION IN THE FOOT

POSTERO LATERAL INCISION

POSTERO LATERAL INCISION WITH GOOD EXPOSURE OF ANKLE,

SUBTALAR JOINT AND ENTIRE PATHOLOGICAL ANATOMY

MEDIAL INCISION



CASE - I

GRADE IV UNILATERAL CLUBFOOT

PRE OPERATIVE PICTURE

POST OPERATIVE PICTURE SHOWING PLANTI GRADE FOOT WITH GOOD SURGICAL SCAR – GRADE I

CASE – II

GRADE IV BILATERAL CLUB FOOT PREOPERATIVE PICTURE

POSTOPERATIVE PICTURE SHOWING GOOD CORRECTION, PLANTIGRADE FOOT AND GOOD SURGICAL SCAR – GRADE I

CASE – III

GRADE – III UNILATERAL CLUB FOOT
PREOPERATIVE PICTURE

POSTOPERATIVE PICTURE SHOWING GOOD CORRECTION AND PLANTIGRADE FOOT

CASE – IV

GRADE – IV UNILATERAL CLUB FOOT

PREOPERATIVE PICTURE

POSTOPERATIVE PICTURE SHOWING RESIDUAL FORE FOOT ADDUCTION AND SUPINATION - GRADE II

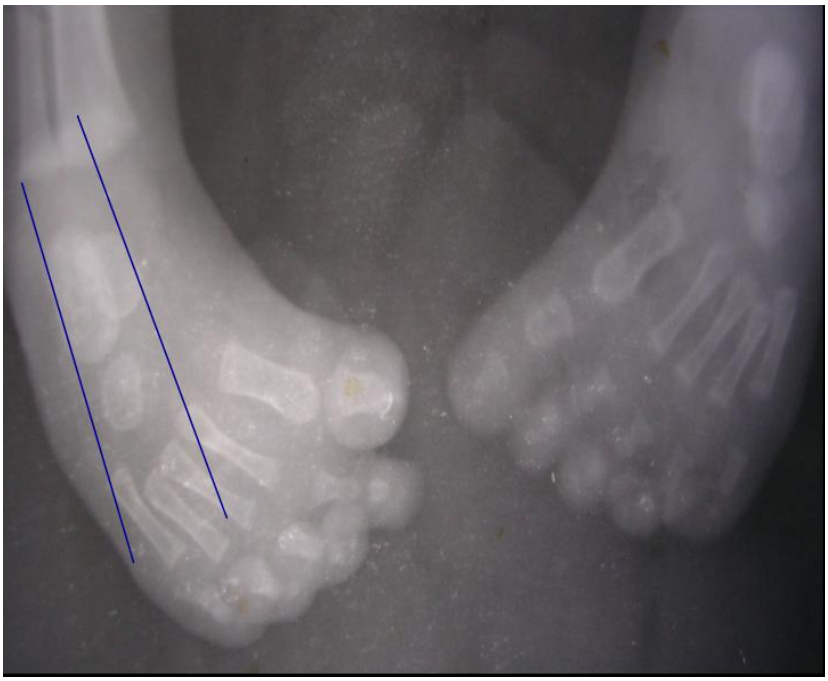
CASE – V

GRADE – IV UNILATERAL CLUB FOOT

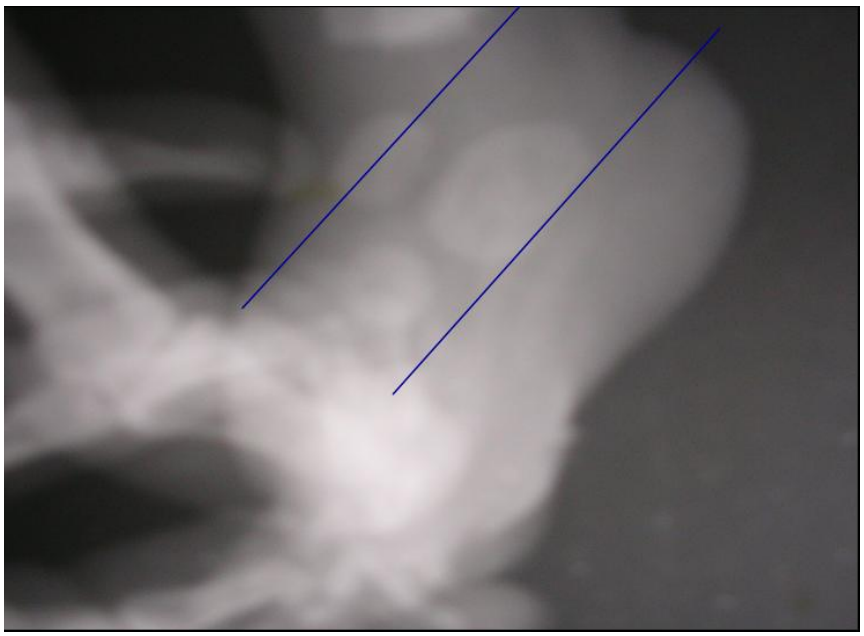
PREOPERATIVE PICTURE

POSTOPERATIVE PICTURE SHOWING RESIDUAL FORE FOOT ADDUCTION - GRADE-II

ANTEROPOSTERIOR PREOPERATIVE RADIOGRAPH

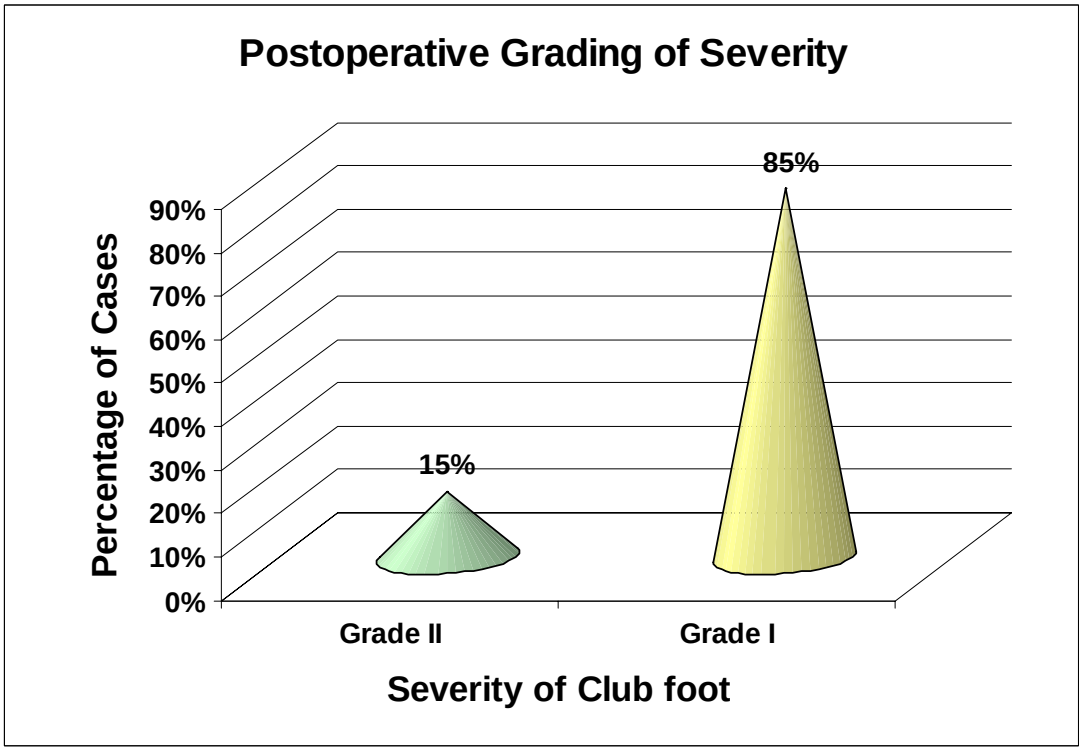


LATERAL PREOPERATIVE RADIOGRAPH



ANTEROPOSTERIOR POSTOPERATIVE RADIOGRAPH SHOWING CORRECTION ACHIEVED

LATERAL POSTOPERATIVE RADIOGRAPH SHOWING CORRECTION ACHIEVED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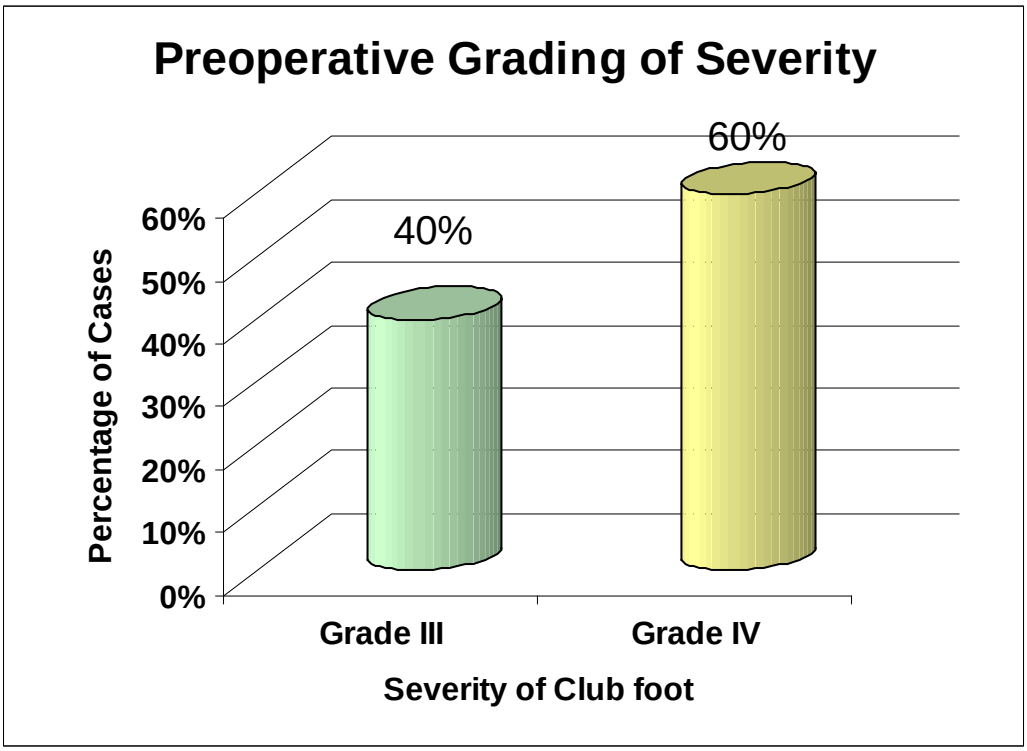
Percentage of Cases
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
85%
15%
Grade II
Grade I
Severity of Club foot


Preoperative Grading of Severity
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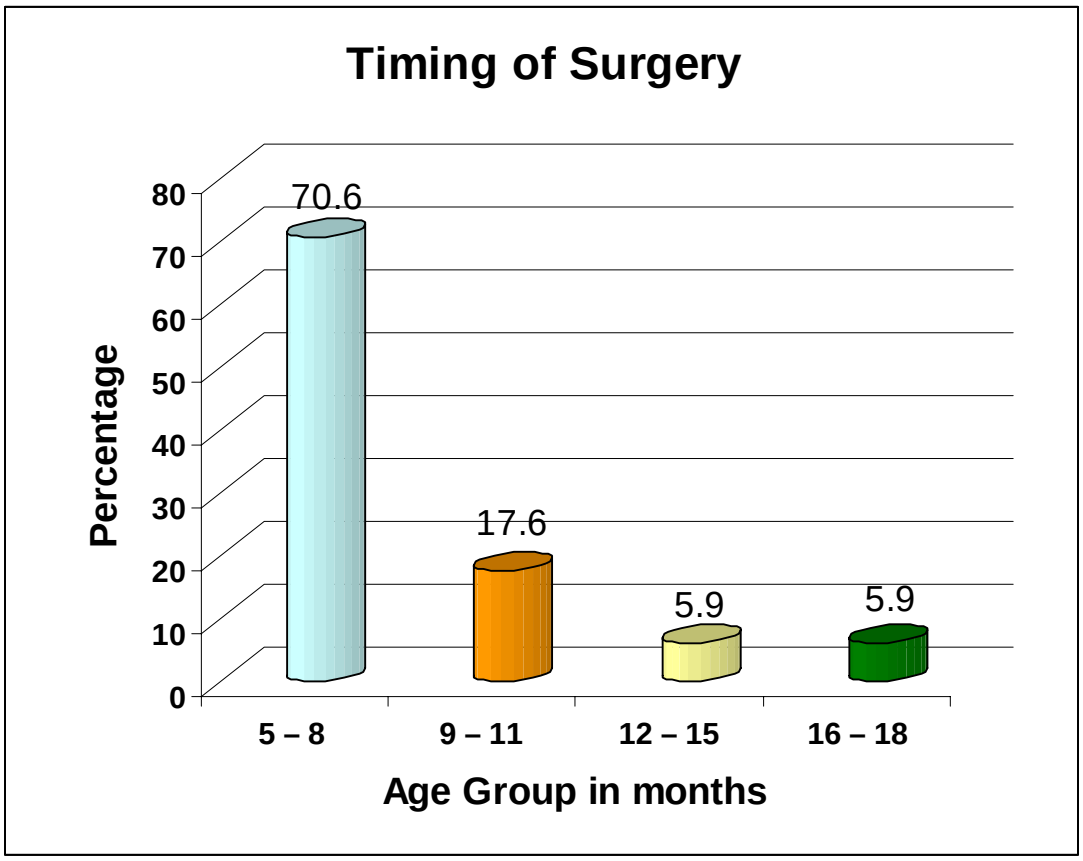
40%
60%
50%
40%
30%
20%
10%
0%
Percentage of Cases
Grade III
Grade IV
Severity of Club foot


Timing of Surgery
Percentage
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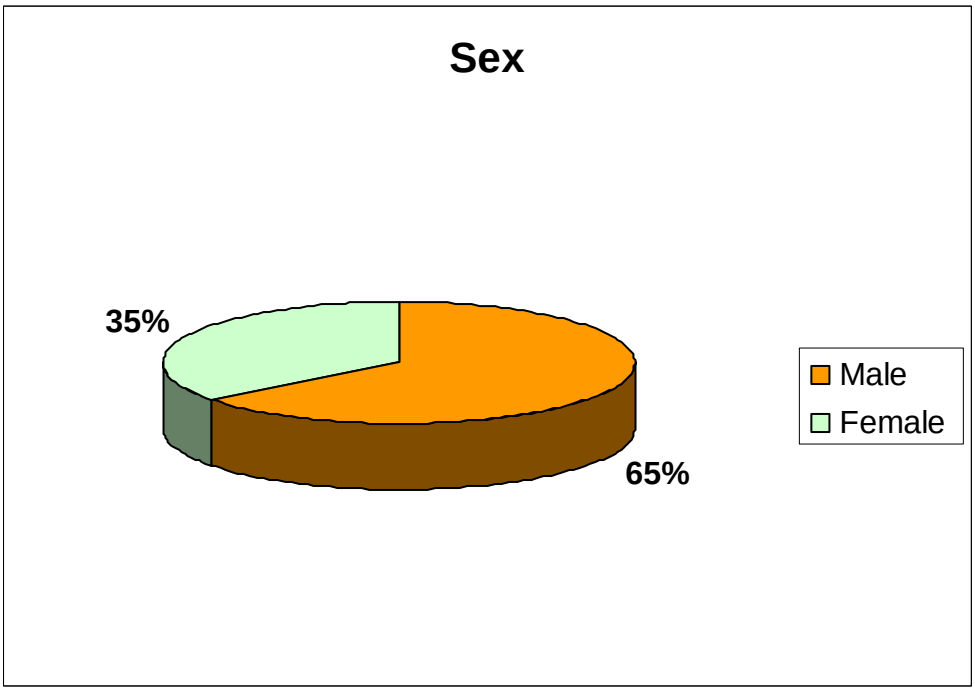
70
60
50
40
30
20
10
0
70.6
17.6
5.9
5.9
5 – 8
9 – 11
12 – 15
16 – 18
Age Group in months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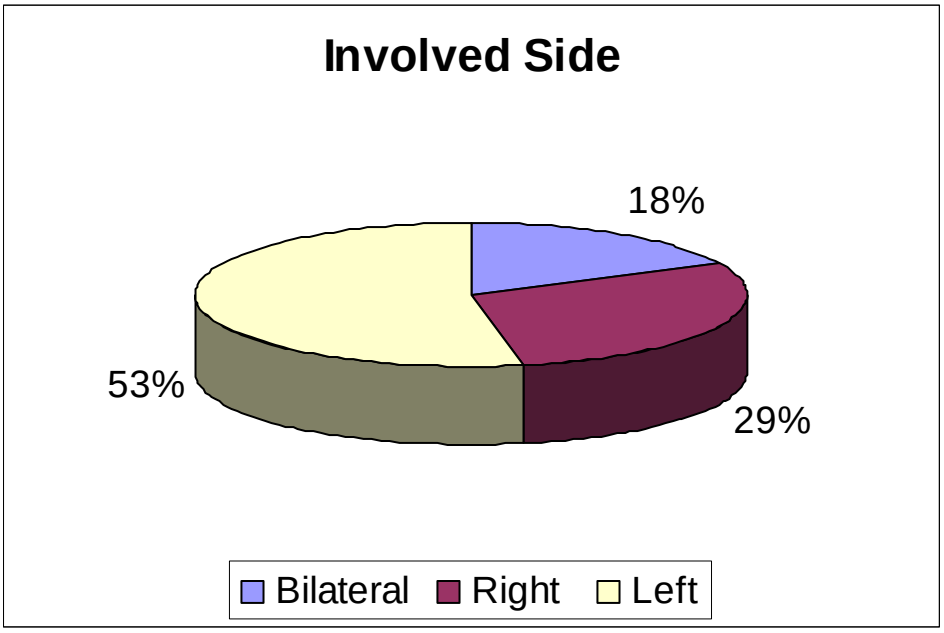
Female


Involved Side
18%
53%
29%
Bilateral
Right
Left

SL.No	Name	Age (Months)	Sex	IP No.	Preoperative Grade	UNI/BIL (INVOLVED SIDE)	Postoperative Grade	Complications	Follow up (months)
1	GAJENDRAN	14	M	336117	IV	UNI[L]	II	Residual forefoot adduction/supination	14
2	HARIHARAN	5	M	337411	III	UNI[R]	I	-	14
3	B/O RAJALAKSHMI	7	M	346396	III	UNI[L]	I	-	12
4	JOTHILAKSHMI	9	F	348634	IV	UNI[L]	II	Residual forefoot adduction	12
5	JAKKAYAPANDIYAN	6	M	350634	IV	BIL	I	-	12
6	ARUN	11	M	350556	III	UNI[L]	I	-	12
7	SHAHJAHAN	5	M	351026	IV	UNI[L]	II	Residual forefoot adduction	12
8	EBINEZAAR	6	M	352025	IV	UNI[L]	I	-	10
9	JAMINABANU	11	F	356621	IV	UNI[R]	I	-	10
10	SABAREESWARAN	5	M	368552	IV	BIL	I	-	10
11	GENITHAMARY	5	F	375682	III	UNI[R]	I	-	10
12	ABDULLAH	5	M	377113	III	UNI[R]	I	-	8
13	MUTHUMARI	18	F	379369	IV	UNI[L]	I	-	8
14	LAWRENCE KRUBAKARA	7	M	394758	III	UNI[L]	I	-	8
15	SIVAYAZHINI	7	F	404599	IV	BIL	I	-	6
16	RAMU	7	M	400920	III	UNI[R]	I	-	6
17	NAGADHARSHINI	8	F	401974	III	UNI[L]	I	-	6
		Avg 8 months						-	Avg 10 months